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(58) Field of Search
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(54) Rotary cone rock bit with ultra hard heel row inserts

(57) A rotary cone rock bit for drilling boreholes in an earthen formation has one or more rotary cones 16 rotatively retained on a journal bearing 19 connected to the rock bit body. These rotary cones 16 have a plurality of tungsten carbide inserts 18 and a gage row 15 of tungsten carbide inserts for drilling the hole diameter. A circumferential heel row 30 has extended ultra hard shaped cutters spaced within the heel row. Each of the shaped cutters has a cutting edge 36 that shears a borehole wall formed by the formation as the rotary cone rotates against a bottom of the borehole. The shaped cutters serve to maintain the borehole diameter and to divert formation debris away from bearing surfaces formed between the rotary cone and the journal bearing. Preferably the ultra hard cutters have a polycrystalline diamond cutting edge.

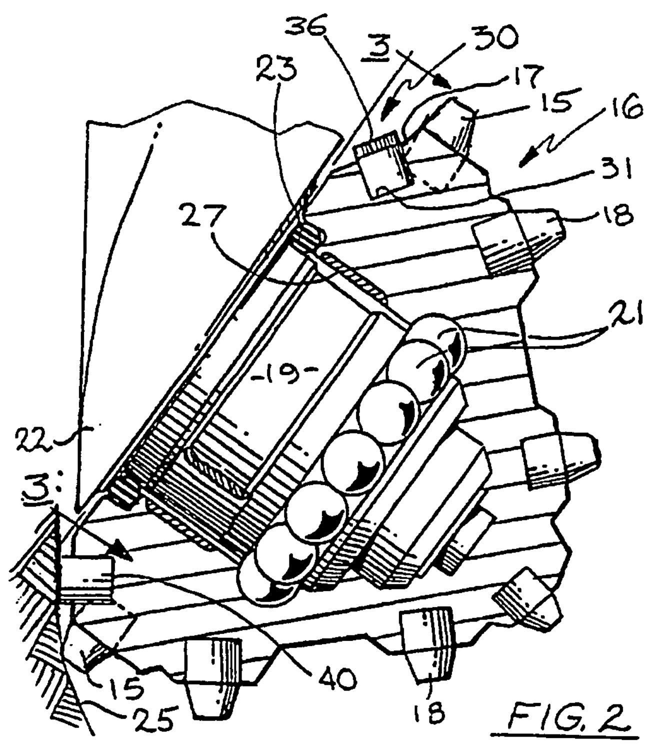

FIG. 2

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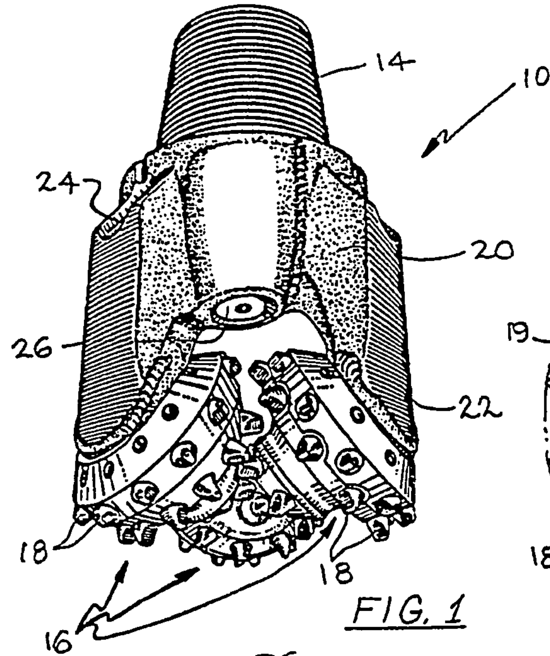

FIG. 1

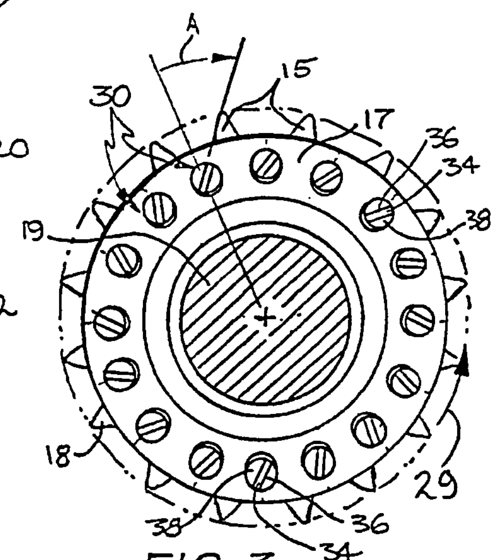

FIG. 3

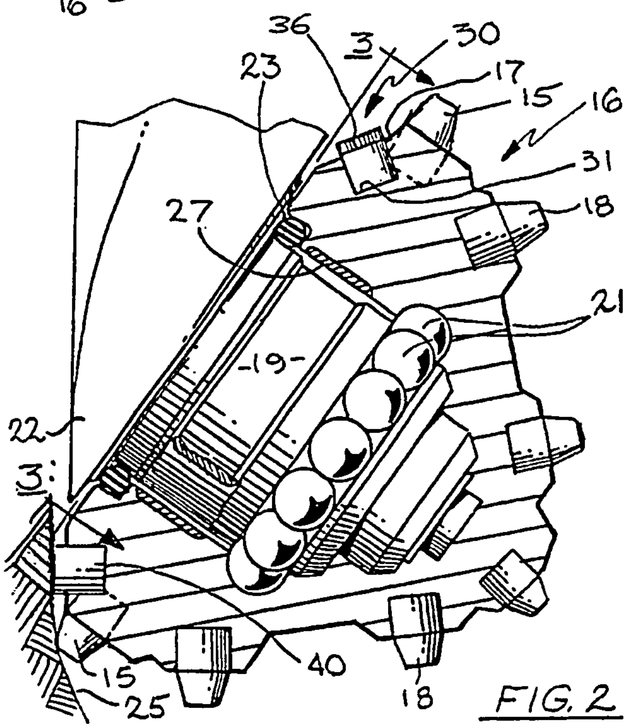

FIG. 2

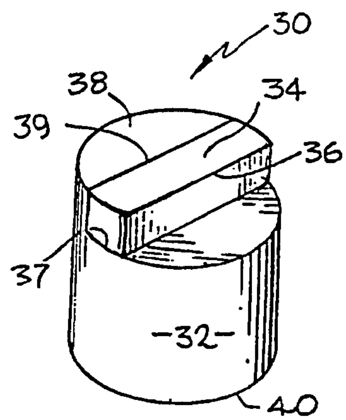

FIG. 4

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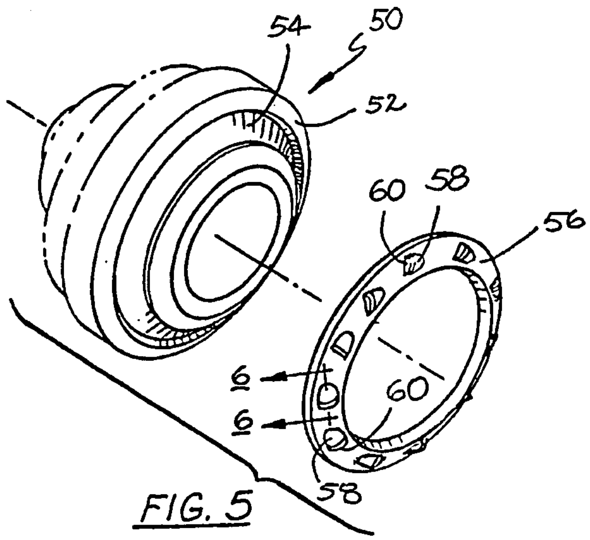

FIG. 5

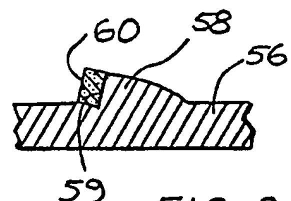

FIG. 6

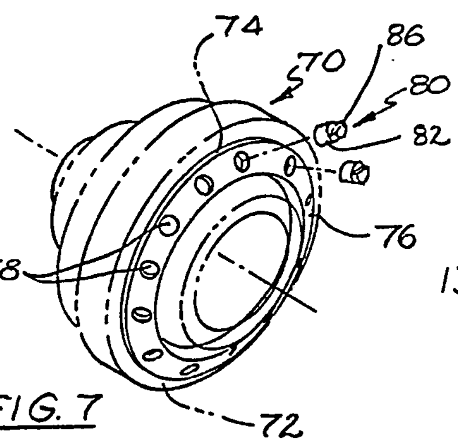

FIG. 7

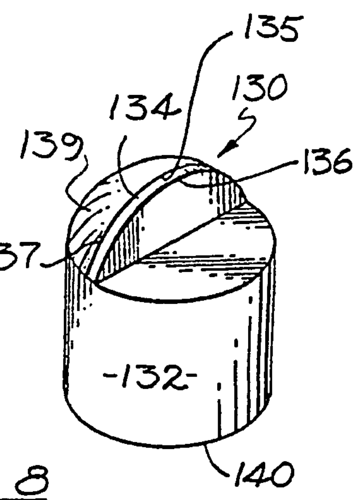

FIG. 8

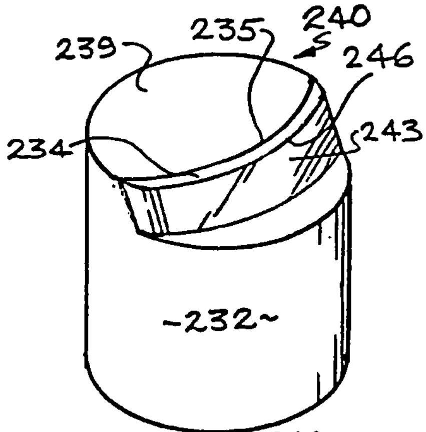

FIG. 9

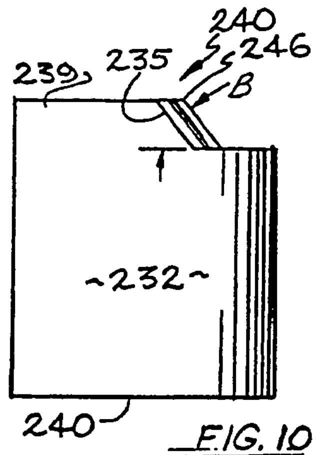

FIG. 10

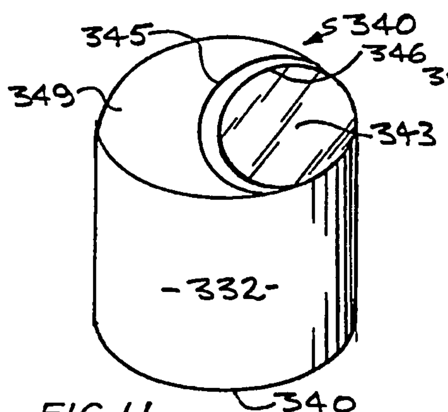

FIG. 11

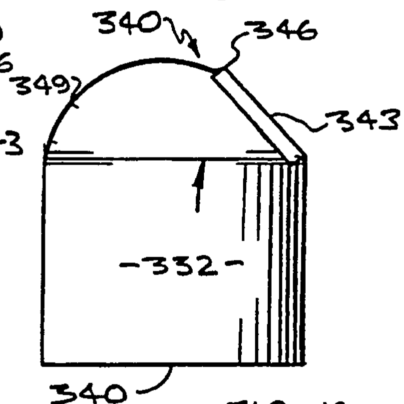

FIG. 12

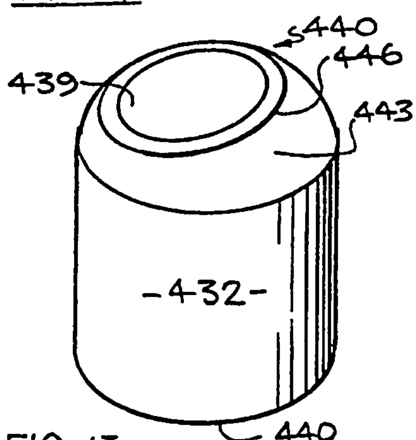

FIG. 13

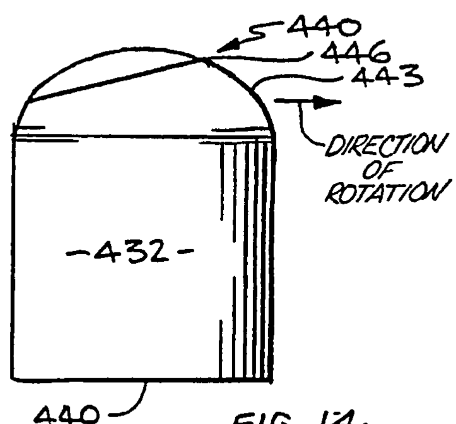

FIG. 14

ROTARY CONE ROCK BIT WITH ULTRA HARD HEEL ROW INSERTS

BACKGROUND

This invention relates to the cutting structure formed on rotary cones of rotary cone rock bits utilized to drill boreholes in an earthen formation. More particularly, this invention relates to the use of shaped diamond or other ultra hard material insert cutters in the heel row of each of the rotary cones associated with the drill bit for shearing and maintaining the gage bore diameter of the formation. These ultra hard materials include cubic boron nitride and/or diamond/refractory metal carbide composites.

Inserts with a polycrystalline diamond surface have been tried before in roller cone rock bits in an attempt to extend the useful life of a rock bit as it works in a borehole.

U.S. Patent Number 4,940,099 teaches the utilization of alternating cemented tungsten carbide inserts and diamond coated inserts in each row formed on a rock bit cutter cone. Both the heel row (which rubs on the formation) and the gage row (which drills the borehole to the desired gage or diameter) as well as successive concentric rows terminating at the apex of the truncated cone having alternating tungsten carbide chisel inserts and diamond coated inserts. The

heel row adjacent the cone mouth opening alternates flush mounted tungsten carbide inserts with harder tungsten carbide inserts with a layer of polycrystalline diamond bonded thereto. The alternating gage row inserts extend from the cone surface and serve to cut the gage of the borehole.

It is well known in the art to utilize flush type inserts in the heel row of roller cones primarily to minimize erosion of the cones due to the passage of drilling fluid and formation detritus between the heel and gage rows of the cones and the borehole wall. The '099 patent, while it teaches alternating hard and soft flush inserts in the heel row also teaches that it is more important that the larger diameter rows, particularly the gage row, be provided with an intermingled pattern of soft and hard inserts to facilitate drilling differing earthen formations.

Maintenance of a constant diameter borehole throughout the drilling operation is of paramount importance in cost-per-foot drilling costs. If a rock bit should drill undergage it causes a following, same diameter bit to pinch due to the undersized hole condition. This usually results in a ruined rock bit and is the cause of another trip out of the hole, followed by a reaming operation, all of which is time consuming and very costly. Moreover, directional drilling of boreholes has become increasingly more prevalent for more efficient extraction of petroleum from known oil reserves. State of the art rock bits such as the foregoing patent are ill suited for directional drilling applications because the heel and gage rows formed on the cones are primarily designed to maintain the gage diameter of the hole.

Flush type heel row inserts ultimately act as a passive bearing surface when the heel of the cone is in contact with the borehole wall. When the entire heel surface of each of the cones is in contact with the

borehole wall, the cones are subjected to tremendous inthrust loads. The inthrust loads tend to pinch the bit, damage the cone and journal bearings and cause heat checking of the tungsten carbide inserts.

Where it becomes necessary to deviate from the vertical in directional drilling operations, the bits will not adequately invade the borehole sidewall to effect a turn from the vertical. Thus, rock bits with side cutting capability have a decided advantage over state of the art roller cone rock bits.

U.S. Patent Number 5,131,480, hereby incorporated by reference, teaches the use of extended tungsten carbide inserts in a recessed heel row in a milled tooth rotary cone rock bit. While this patented feature greatly improved directional drilling capabilities, the rounded projections on the heel row inserts somewhat limited the rock shearing function necessary for aggressive side cutting while turning from a straight drill run. Also, the tungsten carbide wears, allowing an undergage condition.

It was found through experimentation that if drilling energy is not put into shearing the rock, the energy then converts into pushing the cone away from the rock formation resulting in the heretofore mentioned inthrust condition with all of its disadvantages.

Thus, it is desirable to have a roller cone rock bit with enhanced side cutting capabilities to maintain full gage borehole diameter for vertical drilling applications.

BRIEF SUMMARY OF THE INVENTION

A rotary cone rock bit for drilling boreholes in an earthen formation has a rock bit body and a plurality of rotary cones rotatively retained on respective journal bearings on the rock bit body. A plurality of cemented tungsten carbide inserts in

each of the rotary cones drill a borehole. A circumferential gage row of cemented tungsten carbide inserts in each of the rotary cones drills a borehole to a desired diameter. A circumferential heel row with extended ultra hard shaped cutters spaced within the heel row serves to maintain a desired borehole diameter. Each of the shaped cutters has an ultra hard cutting edge arranged for shearing a borehole wall in earthen formation as the rotary cone rotates against a bottom of the borehole.

The hard wear material is preferably polycrystalline diamond that protrudes from the heel row of each cone. Preferably the cutting edges are skewed for both shearing the side wall of the borehole and deflecting debris away from the cone bearings as the roller cones rotate on the bottom of a borehole.

BRIEF DESCRIPTION OF THE DRAWINGS

The above noted features and advantages of the present invention will be more fully understood upon a study of the following description in conjunction with the detailed drawings wherein:

FIGURE 1 is a perspective view of a sealed bearing rotary cone rock bit;

FIGURE 2 is a partially cut away cross-section of a roller cone mounted to a journal bearing ;

FIGURE 3 is an end view of the cone taken through 3-3 of Figure 2 illustrating the heel surface of the cone and the orientation of each of the shaped diamond cutters equidistantly placed around the heel row;

FIGURE 4 is an enlarged perspective view of a single shaped diamond cutter illustrating the cutting edge of the insert that may be oriented in the heel row to aggressively shear into a side wall of a formation and to deflect detritus from the bearing

surfaces as the cone rotates in a formation;

FIGURE 5 is an exploded perspective view, partially in phantom, of an alternative embodiment wherein the heel row is formed from a hard metal conical ring element with diamond cutter segments oriented and bonded thereto, the conical ring being subsequently metallurgically attached to a conically formed groove formed in the cone adjacent the heel row;

FIGURE 6 is a section taken through 6-6 of Figure 5 illustrating the diamond cutter segment mounted to the conical heel row ring with a built up backing portion behind each of the cutter segments for support thereof;

FIGURE 7 is an exploded perspective view partially in phantom of yet another alternative embodiment showing a conical heel row ring element with equidistantly and circumferentially spaced shaped insert cutter pockets formed in the conical ring, with shaped diamond inserts being oriented and attached within the pockets;

FIGURE 8 is a perspective view of an alternative diamond cutter with a hemispherical cutting end forming an arcuate cutting surface;

FIGURE 9 is a perspective view of an alternative diamond cutter insert with a back rake angle and a convex cutting edge surface;

FIGURE 10 is a side view of the insert of Figure 9;

FIGURE 11 is a perspective view of another embodiment of a diamond cutter insert with a flat or slightly curved cutting face formed in a domed insert, the diamond cutting face forming a back rake angle;

FIGURE 12 is a side view of the insert of Figure 11;

FIGURE 13 is yet another embodiment of a diamond

cutter insert wherein the domed insert cap is layered with polycrystalline diamond and a cutting edge is formed by removing an angled portion through a plane taken through the apex of the dome, the removed section exposing the tungsten carbide base and a ring of diamond which, at its leading edge serves to cut the gage of a borehole; and

FIGURE 14 is a side view of the insert of Figure 13.

DESCRIPTION

Boreholes are commonly drilled with rock bits having rotary cones with cemented carbide inserts interference fitted within sockets formed by the cones. Such a rock bit generally designated as 10 has a steel body 20 with threads 14 formed at an upper pin end and three depending legs 22 at its lower end. Three cutter cones generally designated as 16 are rotatively mounted on the three legs at the lower end of the bit body. A plurality of cemented tungsten carbide inserts 18 are press fitted or interference fitted into insert sockets formed in the surface of the cones 16. Lubricant is provided to the journals 19 (Fig. 2) on which the cones are mounted from each of three grease reservoirs 24 in the body.

When the rock bit is used, it is threaded onto the lower end of a drill string and lowered into a well or borehole. The bit is rotated with the carbide inserts in the cones engaging the bottom of the hole. As the bit rotates, the cones 16 rotate on the bearing journals 19 cantilevered from the body and essentially roll around the bottom of the hole 25. The weight of the bit is applied to the rock formation by the carbide inserts and the rock is thereby crushed and chipped by the inserts. A drilling fluid is pumped down the drill string to the bottom of the hole and ejected from the bit body

through nozzles 26. The drilling fluid then travels up the annulus formed between the outside drill pipe wall and the borehole formation walls. The drilling fluid provides cooling and removes the chips from the bottom of the borehole.

With reference now to Figure 2, the lower portion of the leg 22 provides the journal bearing 19 on which cone 16 rotates. The cone is retained on the bearing by a plurality of cone retention balls 21 confined by a pair of opposing ball races formed in the journal and the cone. The cone includes an annular heel row 17 positioned between the gage row inserts 15 and a bearing cavity 27 formed in the cone. A multiplicity of protruding heel row insert cutters generally designated as 30 are about equidistantly spaced around the heel row 17. The protruding heel row inserts 30 and the gage row inserts 15 coact to primarily cut the gage diameter of the borehole 25. The multiplicity of remaining inserts 18 in concentric rows crush and chip the earthen formation as heretofore described.

With reference now to Figures 3 and 4, each of the heel row inserts or cutters 30 is, for example, formed from a cemented tungsten carbide body 32 having a base end 40 and a cutter end 38. The cutter end 38 supports an ultra hard cutter element 34 (preferably polycrystalline diamond) that is, for example, metallurgically bonded or brazed to the cutting end at juncture 37. An end backup support 38 for the ultra hard cutter is important in that it serves to help prevent separation of the cutter from the carbide body 32. In addition, the backup support 38 allows the trailing edge 39 of the cutter 34 to be supported to prevent cutter breakage due to elastic rebound that often occurs during drilling operations.

The cutter element 34, for example, defines a straight cutting edge 36 that may be substantially

radially oriented with respect to an axis of the cone 16. The cutting edge 36 may however, be slightly convex as is illustrated with respect to Figures 8 and 9.

With specific reference to Figure 3, each of the cutters 30 is preferably skewed with a negative side rake angle "A" with respect to a radial line from the axis of the cone. This orientation effectively shears the formation while simultaneously directing the debris away from the sealed bearing surfaces formed between the cone 16 and the journal 19 when the cone rotates in direction indicated by an arrow 29. The side rake angle may be between 2 and 20 degrees. The preferred side rake angle is 5°. The side rake angle distributes the forces subjected to the cutting edge effectively to prevent "balling" of the bit (a condition where debris piles up against the cutting face of the cutting element or edge loading of the cutting edge of the cutters.

Each of the heel row diamond insert cutters 30 is preferably interference fitted within an insert retention socket 31 formed in the heel row. The diamond material may be composed of polycrystalline material pressed in a super pressure press of the type taught in U.S. Patent Number 4,604,106. Moreover, the diamond cutters may be fabricated from a composite of tungsten carbide material impregnated with diamond particles. A process for making such material is set forth in U.S. Patent Numbers 4,966,627 and 5,045,092. Additionally, the ultra hard cutters may be fabricated from composites of cubic boron nitride (CBN) and refractory metal carbides such as tungsten carbide.

The exploded perspective view of Figure 5 illustrates an alternative embodiment of the invention wherein the aggressive heel row cutting action is incorporated in a conically shaped ring 56

that is insertable within a complementary groove 54 formed in a cone generally designated as 50. Diamond cutter segments 60 are metallurgically bonded to a recess 59 formed in the ring 56 (Fig. 6). Each of the diamond cutters 60 is preferably positioned with a negative side rake angle with respect to a radial line from an axis of the cone 50 such as that shown in Figure 3. Furthermore, each cutter 60 is backed up by support 58 formed on the conical ring 56.

The ring may, for example, be machined from a metal such as steel or it may be formed in a mold utilizing powdered tungsten carbide material; the diamond cutter recess 59 and backup portion 58 being formed in a female mold (not shown). The diamond cutters 60 are subsequently metallurgically bonded (preferably brazed) into their recesses 59. The finished ring 56 is then brazed within the groove 54 in the cone. If desired, the ring could be segmented into, for example, four 120° segments and brazed in place for ease of fabrication.

Figure 7 is yet another embodiment of the invention wherein a conical ring 76 (similar to the ring 56 of Figure 5) is formed either by a powder metallurgy process or be machining. The conical ring includes a series of equidistantly spaced insert sockets 78 around the heel row surface of the ring. Diamond cutter inserts generally designated as 80 are brazed within each of the sockets 78 and the completed ring assembly is subsequently metallurgically bonded within a complementary groove 74 formed in heel surface 72 of the cone. The inserts 80 are fabricated with, for example, a straight diamond cutting edge 86 and a base portion having a depth sufficient to be bonded within the sockets formed in the conical ring. The cutting edge 86 is angled with a negative side rake angle with respect to a radial line from an axis of the cone 70

at an angle of up to 35 degrees. Again, the ring 70 may be fabricated from cemented tungsten carbide or similar erosion resisting material.

Figure 8 illustrates another embodiment wherein the insert 130 is hemispherical at its cutting end. The cutting edge 136 on a half disc diamond segment 134 secured the insert body is arcuate conforming to the circular end of the insert. A backup portion 139 serves to back up the diamond composite bonded at juncture 135 of the exposed end of the cutter. A braze joint 137, for example, secures the half disc diamond segment 134 to the backup portion.

Figures 9 and 10 illustrate an alternative embodiment of diamond insert 240 similar to the insert 30 of Figure 4. The cutting face 243, however, is arcuate or convexly curved and raked back at an angle B that is preferably between 0 and 75 degrees relative to a tangent to the heel row to maintain the diamond cutting face 243 in a compressive mode while maintaining maximum shearing action as the cutting edge 246 works against a rock formation. A back support area 239 serves to support the curved diamond cutter 234, especially during drilling operations that often result in elastic rebound action that the cutters are subjected to.

Figures 11 and 12 illustrate still another embodiment having a domed tungsten carbide insert 340 with an angled plane surface 345 formed in a leading edge thereof. A diamond cutter 343 is bonded to the surface 345 at a back rake angle of about 45°.

The diamond insert of Figures 13 and 14 is a domed diamond layered insert 440 with a portion of the dome removed along a plane transverse to an axis of the insert to form a leading cutter edge 446 that is aligned substantially in the direction of rotation of the cone. The plane of the section cut through the dome is angled about 80 degrees relative to the

axis of the insert. The arcuate diamond cutting edge 446 is supported by the tungsten carbide portion 439 exposed behind the cutter face 443. The asymmetrical cutting edge 446 created by the angled "slice" through the apex of the dome (shown in phantom in Fig. 14) facilitates the orientation of the rounded cutting edge with respect to the heel row 17 as illustrated in Figure 3.

It will of course be realized that various modifications can be made in the design and operation of the present invention without departing from the spirit thereof. Thus, while the principal preferred construction and mode of operation of the invention have been explained in what is now considered to represent its best embodiments, it should be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

WHAT IS CLAIMED IS:

1. A rotary cone rock bit for drilling boreholes in an earthen formation comprising:

a rock bit body;

a plurality of rotary cones rotatively retained on respective journal bearings on the rock bit body;

a plurality of cemented tungsten carbide inserts in each of the rotary cones;

a circumferential gage row of cemented tungsten carbide inserts in each of the rotary cones for drilling a borehole to a desired diameter; and

a circumferential heel row with extended ultra hard shaped cutters spaced within the heel row, each of said shaped cutters having ultra hard cutting edges arranged for shearing a borehole wall in earthen formation as the rotary cone rotates against a bottom of the borehole, the shaped cutters serving to maintain a desired borehole diameter.

2. A rock bit as set forth in claim 1 wherein the ultra hard shaped cutter edge has a backup support.

3. A rock bit as set forth in either one of claims 1 or 2 wherein the cutting edges of the shaped cutters are skewed relative to a radial line from the axis of the cone at a side rake angle for diverting formation debris away from bearing surfaces formed between the rotary cone and the journal bearing.

4. A rock bit as set forth in any one of the preceding claims wherein the ultra hard cutting edges of the shaped cutters extending from said heel row are formed from diamond.

5. A rock bit as set forth in any one of the preceding claims wherein the cutting edge forms a

substantially straight line across the cutter end.

6. A rock bit as set forth in any one of the preceding claims wherein the cutting edge is convex.

7. A rock bit as set forth in any one of the preceding claims wherein a face of the cutter edge has a back rake angle with respect to a tangent to the heel row.

8. A rock bit as set forth in any one of the preceding claims wherein the second cutter end is about half dome shaped, the diamond cutting edge forming an arcuate surface conforming to the shape of the dome.

9. A rock bit as set forth in any one of the preceding claims wherein the cutting edges of the shaped cutters comprise polycrystalline diamond bonded to a tungsten carbide substrate.

10. A rock bit as set forth in any one of the preceding claims wherein the side rake angle is between two and twenty degrees.

11. A rock bit as set forth in wherein the side rake angle is five degrees.

12. A rock bit as set forth in any one of the preceding claims wherein the extended ultra hard shaped cutters are fabricated from composites of cubic boron nitride and tungsten carbide.

13. A rock bit as set forth in any one of the preceding claims wherein the extended ultra hard shaped cutters are fabricated from composites of diamond and tungsten carbide.

14. A rock bit as set forth in any one of the preceding claims wherein the shaped cutters are tungsten carbide bodied inserts having a first base end and a second cutter end, the second cutter end comprising polycrystalline diamond bonded to a tungsten carbide substrate, the second cutting end of the body serving as backup support for the diamond.

15. A rock bit as set forth in any one of claims 1 to 13 comprising a circumferential heel row ring secured within a complementary heel row groove in the rotary cone, the ring comprising pockets for mounting the shaped cutters and backup means for supporting the shaped cutters.

16. A rock bit as set forth in claim 15 wherein the heel row ring is fabricated from erosion resistant tungsten carbide material.

17. A rock bit as set forth in either one of claims 15 or 16 wherein the heel row ring comprises a plurality of insert holes around the face of the ring, and a plurality of cemented tungsten carbide inserts in the holes, each insert comprising a layer of polycrystalline diamond bonded to the tungsten carbide insert for forming the cutting edge.

18. A rock bit as set forth in any one of claims 15 to 17 wherein the ring is segmented into two or more segments, each segment being secured to the cone.

19. A rock bit substantially as described and illustrated.

P· ·ents Act 1977 **J ·miner's report to the Comptroller under Section 17** **(..e Search report)**	Application number GB 9400012
Relevant Technical Fields (i) UK Cl (Ed.M) E1F (FFD, FGA, FGB, FGC) (ii) Int Cl (Ed.5) E21B	Search Examiner D J HARRISON Date of completion of Search 31 MARCH 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI	Documents considered relevant following a search in respect of Claims :- 1 TO 19

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	EP 0511547 A	(SMITH INTERNATIONAL INC) whole document, but see particularly heel row inserts 25 and column 6 lines 50-54	1, 4
X	US 5119714 A	(HUGHES TOOL CO) whole document, but see particularly heel row inserts 83, Figure 11	1, 4

Databases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).